FNAL to DUSEL long baseline experiment

- Milind Diwan (BNL, USA) 7/16/2009 FNAL meeting
- Issues regarding pressure performance of tubes

Office of Science
U.S. DEPARTMENT OF ENERGY

BROOKHAVEN NATIONAL LABORATORY

PMT considerations

	10 inch R7081	20 inch R3600
Number (25% cov)	~50000	~14000
QE	25%	20%
CE	~80%	~70%
rise time	4 ns	10 ns
Tube length	30 cm	68 cm
Weight	1150 gm	8000 gm
Vol.	~5 lt	~50 lt
pressure rating	0.7Mpa	0.6Mpa
∢ coverage/pmt	0.6 deg	1.1 deg
∢granularity	1.0 deg	2.1 deg

PMT: further choice

Items	Example 12-inch PMT	R7081 10-inch PMT	R5912 8-inch PMT
Diameter	300 mm	253 mm	202 mm
Effective Area	280 mm min.	220 mm min.	190 mm min.
Tube Length	330 mm	245 mm	220 mm
Dynodes	LF/10-stage	LF/10-stage	LF/10-stage
Applied Voltage	1500 V	1500 V	1500 V
GAIN	1.00E+07	1.00E+07	1.00E+07
T.T.S.(FWHM)	2.8 ns	2.9 ns	2.4 ns
P/V Ratio	2.5	2.5	2.5
Dark Counts	10,000 cps	7,000 cps	4,000 cps

NEW !

HAMAMATSU
HAMAMATSU PHOTONICS K.K. Electron Tube Division

R5912	R7081	R8055	R3600-02
R5912-02	R7081-20		R7250

SPECIFICATIONS

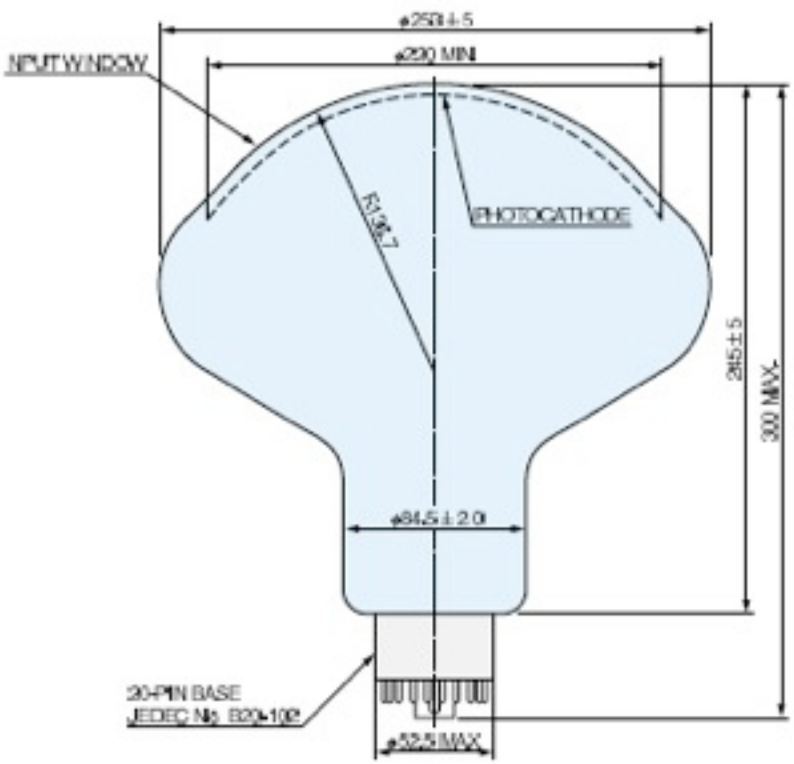
Type No.	Cathode Sensitivity: Luminous (2856 K) Min. (µA/lm)	Luminous (2856 K) Typ. (µA/lm)	Radiant at 420 nm Typ. (mA/W)	Blue Sensitivity Index (CS 5-58) Min.	Blue Sensitivity Index (CS 5-58) Typ.	Quantum Efficiency at 390 nm Typ. (%)	Anode Sensitivity: Luminous (2856 K) Typ. (A/lm)	Radiant at 420 nm Typ. (A/W)	Gain Typ.	Applied Voltage for Typical Gain Typ. (V)
R5912	40	70	72	6.0	9.0	22	700	7.2×10^5	1.0×10^7	1500
R5912-02	40	70	72	6.0	9.0	22	70 000	7.2×10^7	1.0×10^9	1700
R7081	40	80	80	6.0	10.0	25	800	8.0×10^5	1.0×10^7	1500
R7081-20	40	80	80	6.0	10.0	25	80 000	8.0×10^7	1.0×10^9	1700
R8055	35	60	65	5.5	8.0	20	600	6.5×10^5	1.0×10^7	1500
R3600-02	35	60	65	5.5	8.0	20	600	6.5×10^5	1.0×10^7	2000
R7250	35	60	65	5.5	8.0	20	600	6.5×10^5	1.0×10^7	2000

NOTE: Anode characteristics are measured with the voltage distribution ratio shown below.
(   ): Measured with the special voltage distribution ratio (Tapered Divider) shown below.

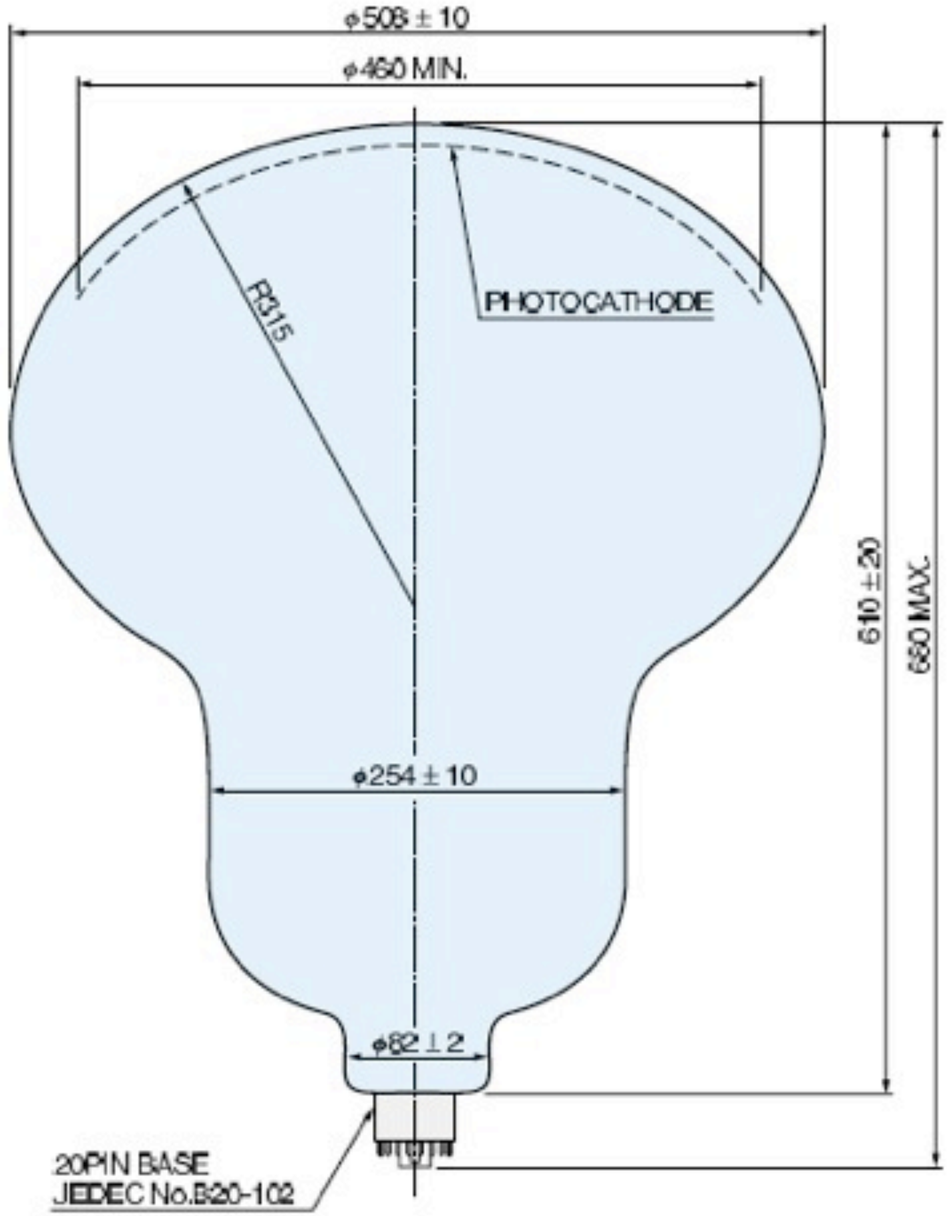
Type No.	Maximum Ratings: Supply Voltage Anode to Cathode (V)	Supply Voltage Anode to Last Dynode (V)	Average Anode Current (mA)	Operating Ambient Temperature (°C)	Storage Temperature (°C)	Pressure (MPa)	Direct Interelectrode Capacitances: Anode to Last Dynode (pF)	Anode to All Other Dynodes (pF)
R5912	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R5912-02	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R7081	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R7081-20	2000	300	0.1	-30 to +50	-30 to +50	0.7	approx. 3	approx. 7
R8055	2500	300	0.1	-30 to +50	-30 to +50	0.15	approx. 10	approx. 20
R3600-02	2500	300	0.1	-30 to +50	-30 to +50	0.6	approx. 36	approx. 40
R7250	2500	300	0.1	-30 to +50	-30 to +50	0.6	approx. 10	approx. 15

We are focussed on the R7081 tube
It is more efficient than the R3600.
25% *R7081 => 35% *R3600

●R7081, R7081-20



●R3600-02



Final choices and notes from meeting with vendor

- R7081 - Pressure rating from manufacturer appears valid and likely conservative.
- R7081 with high QE: already developed. will have same pressure rating.
- Any additional pressure resistance could be implemented, but development will cost $. Vendor has a computer model to determine the tube pressure performance.
- 12 inch tube will likely have same pressure rating. 12 inch tube was to be available in February, but no communication so far.
- 12 inch with high QE is not in the development path currently.

Pressure testing

Have 32 phototubes from Hamamatsu. Pressure vessel from BNL. Evolving testing protocol.

Hamamatsu rating is ~7atm. Tested this tube until it broke at 148 psi (~10atm)

Data so far

PMT	size	Break Press
R7081/ng 1	10inch	148 psi
XP1807 1	12 inch	92 psi
xp18060 1	8 inch	35 psi
R7081 2	10 inch	cycled 132psi
R7081 3	10 inch	cycled 132 psi
R7081 4	10 inch	cycled 132 psi
R7081/lowr1	10 inch	205 psi
R7081/lowr 2	10 inch	218 psi
R7081	10 inch	292 psi
ETL 9350ka	8 inch	68 psi
R7081	10 inch	173 psi

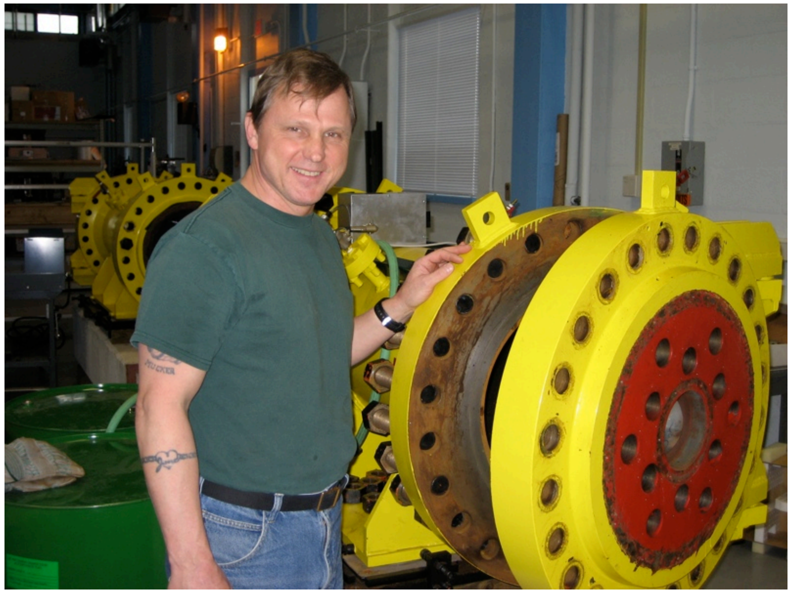
Hamamatsu tested 3 R7081 upto ~10 atm.

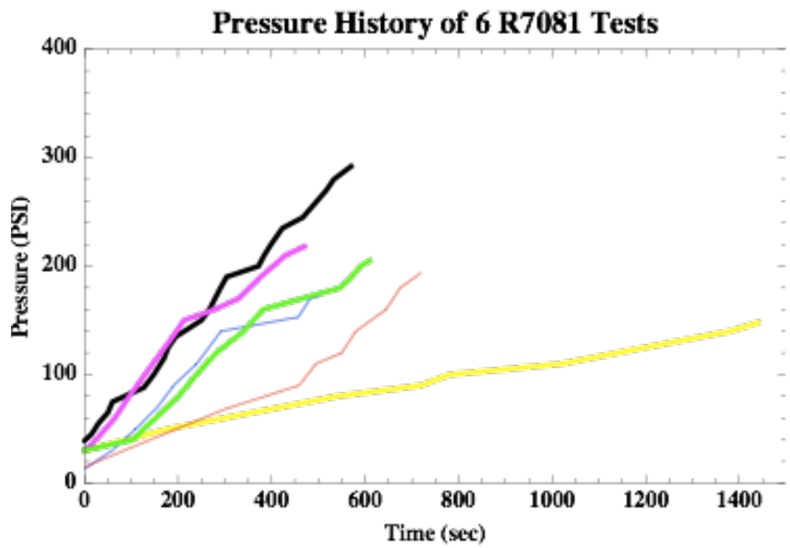
One broke at 10 atm,

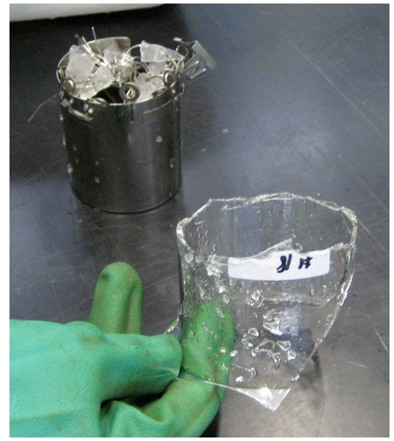
On each tube, there is data on glass thickness, pressure pulse duration, etc.

This it borosilicate glass with thickness ranging from 0.08 to 0.12 inch.

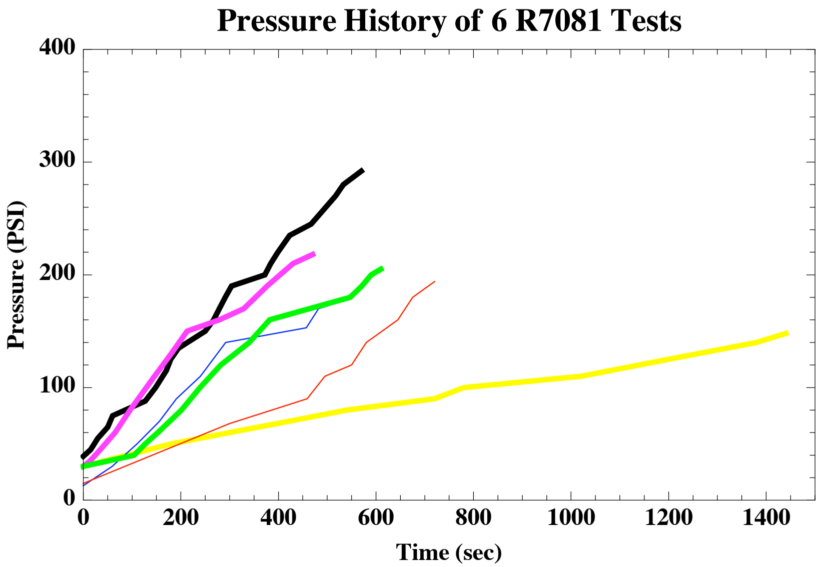
Development of pressure testing at BNL (Diwan, Goett, Sexton)



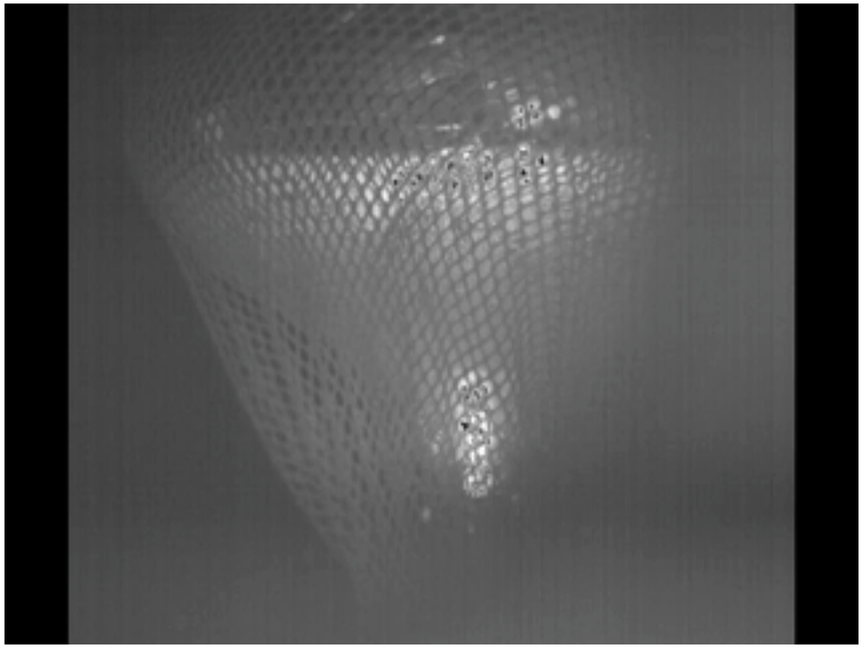




- What have we learned
  - Manufacturers have tubes with very distinct characteristics
  - Failure mode in Hamamatsu hemispherical tubes is at the pins. 7 atm is o.k.
  - Other manufacturers failure may occur at the dome in much more damaging way.
  - Data includes motion picture and recorded pressure pulses.
  - Funded mostly out of LDRD which is finished.

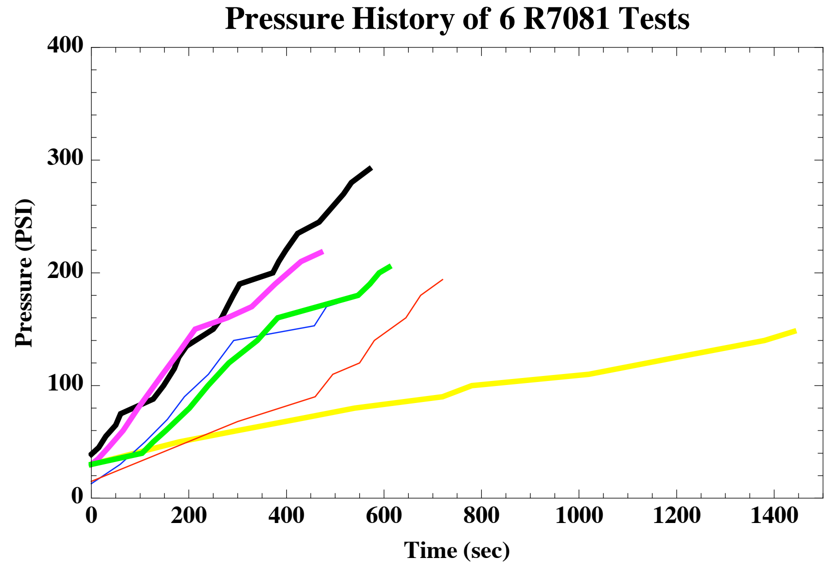


Pressure History of 6 R7081 Tests
Pressure (PSI)
Time (sec)
0
100
200
300
400
0
200
400
600
800
1000
1200
1400



ta4769

TA 4887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Pressure (PSI)
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0
100
200
300
400
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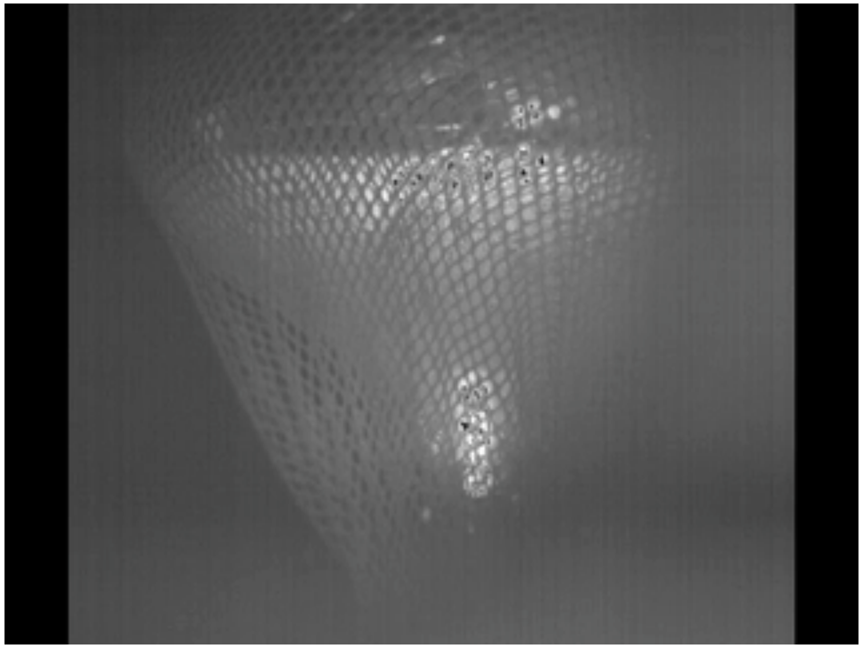
1400



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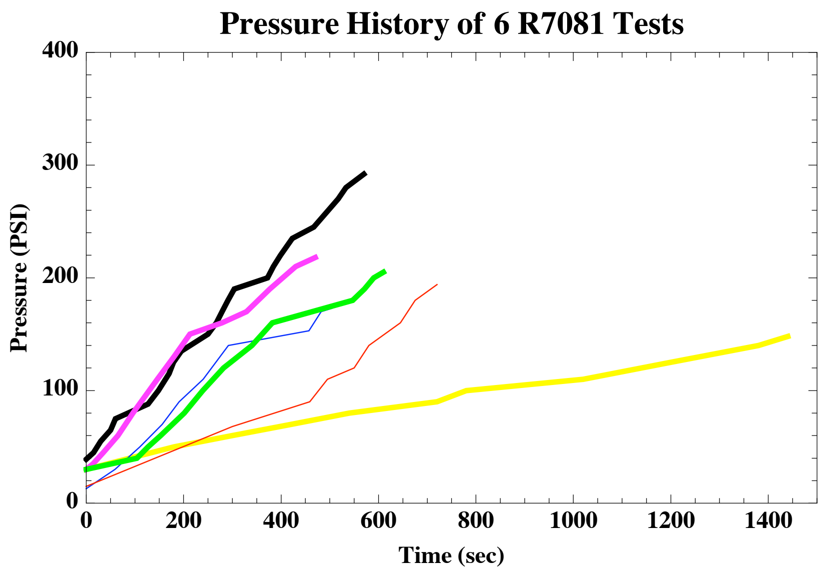

Pressure History of 6 R7081 Tests
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Time (sec)
0
100
200
300
400
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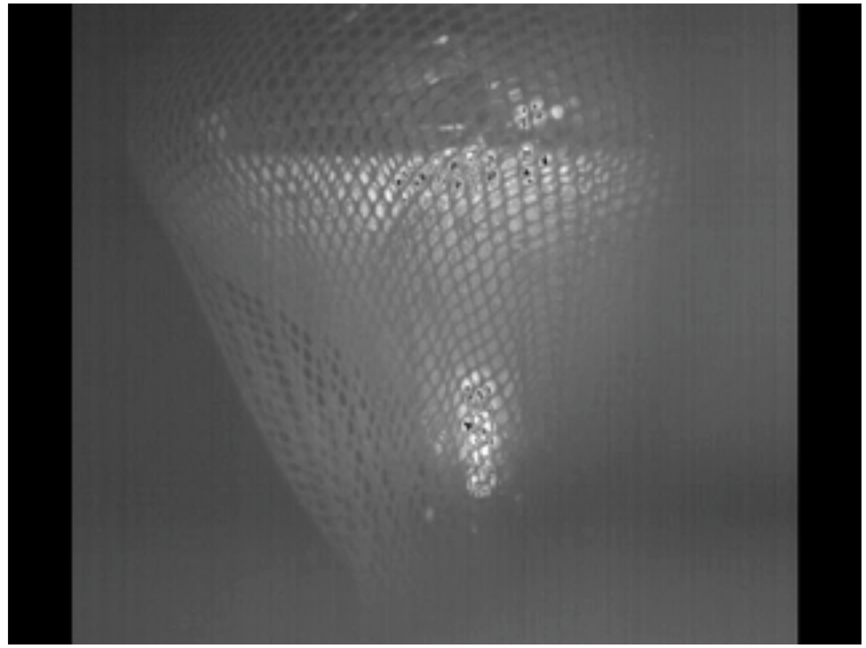

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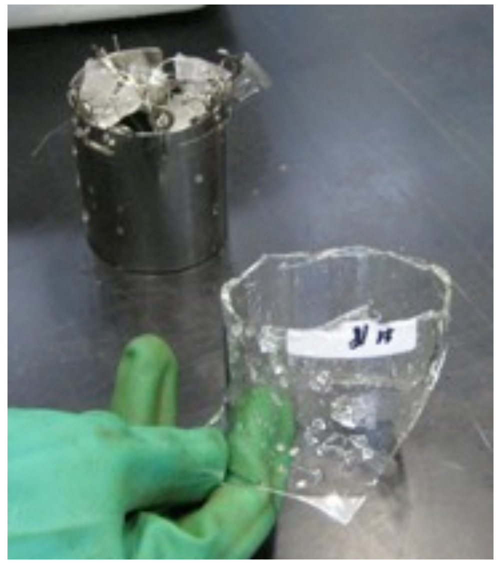


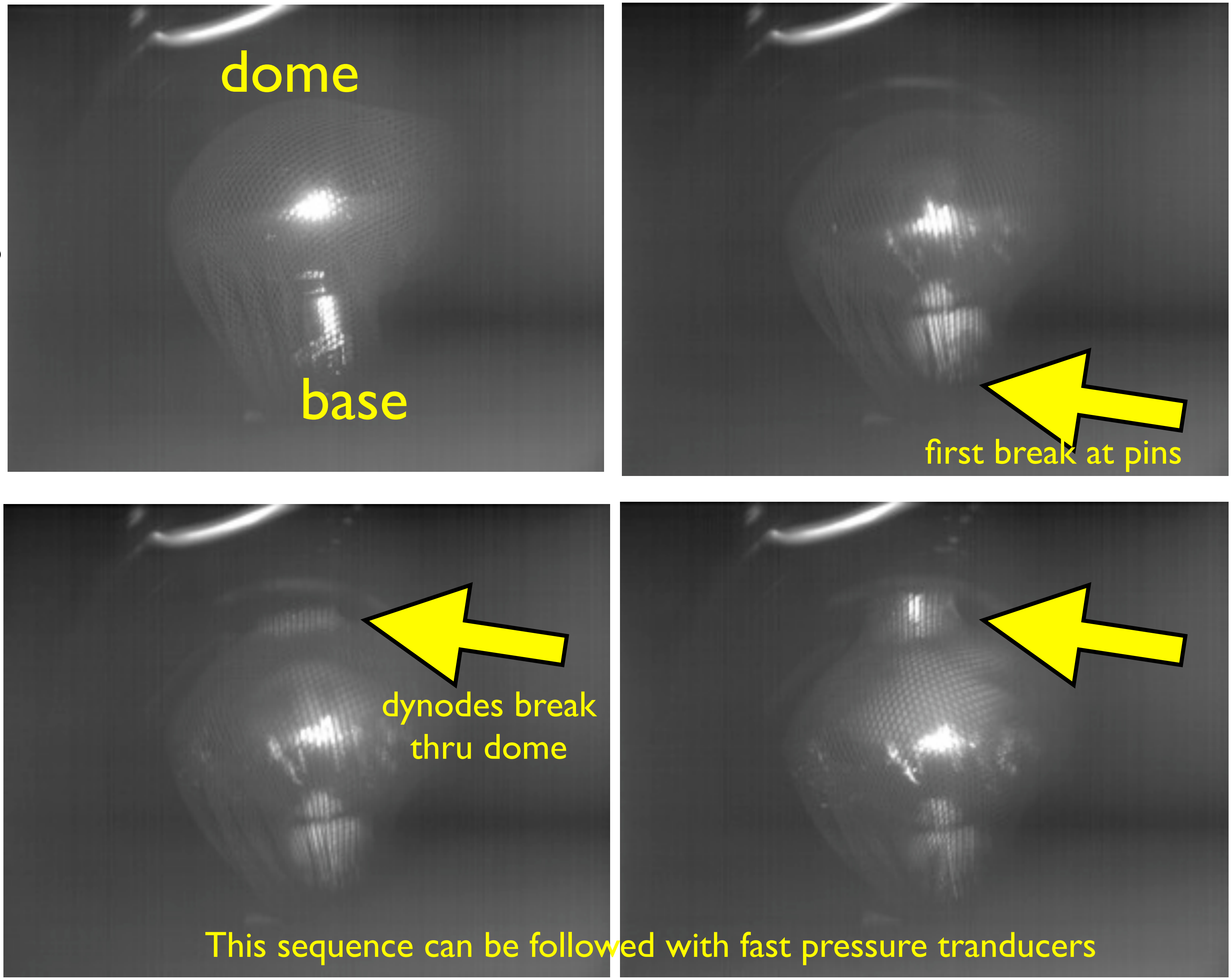
Typical R7081 failure
(TA3085 failed at 13.4 bar)

0 ms

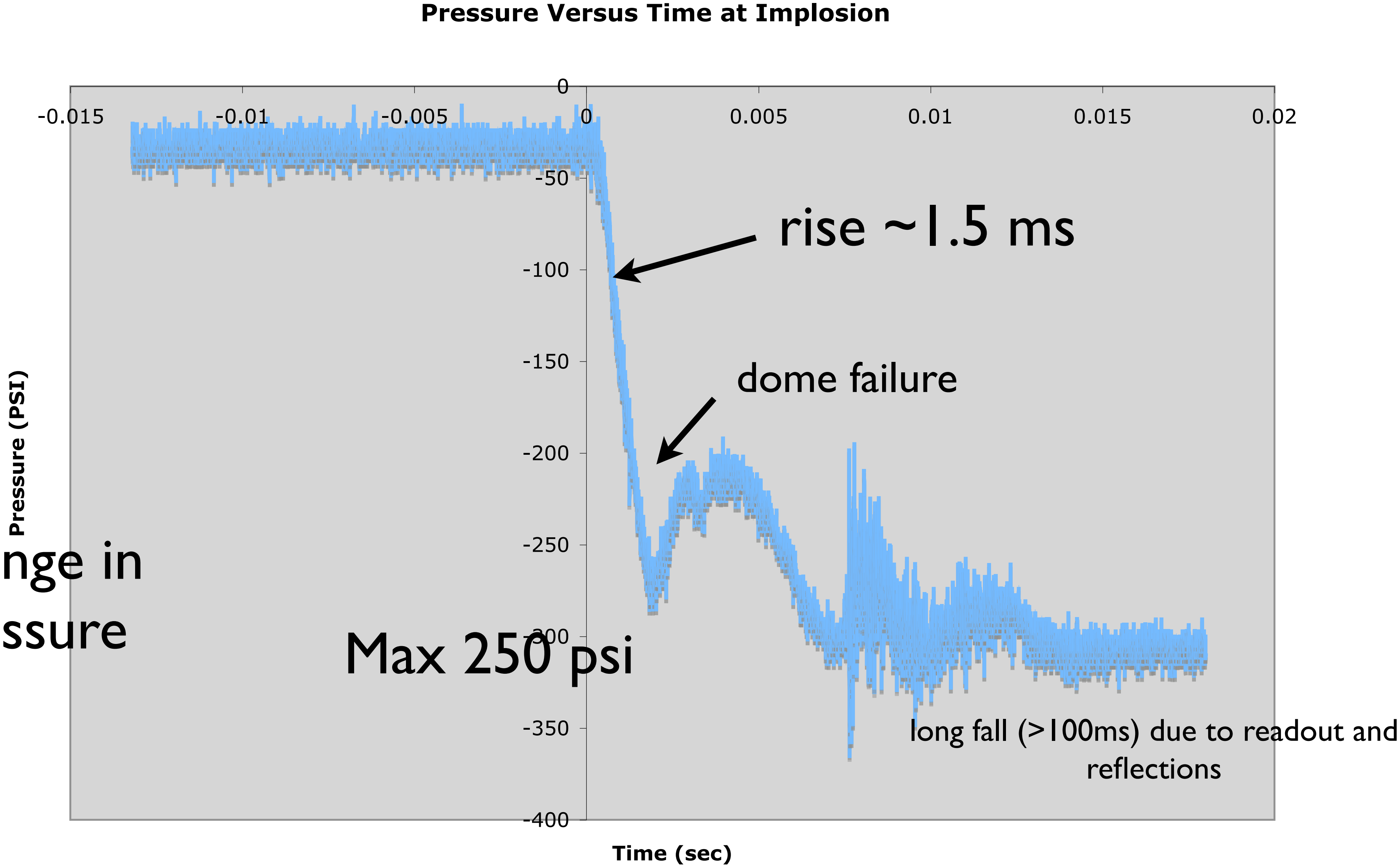
2 ms

4 ms

6 ms



Typical R7081 (ta3085 at 13.4 bar (194 psi))



Change in Pressure

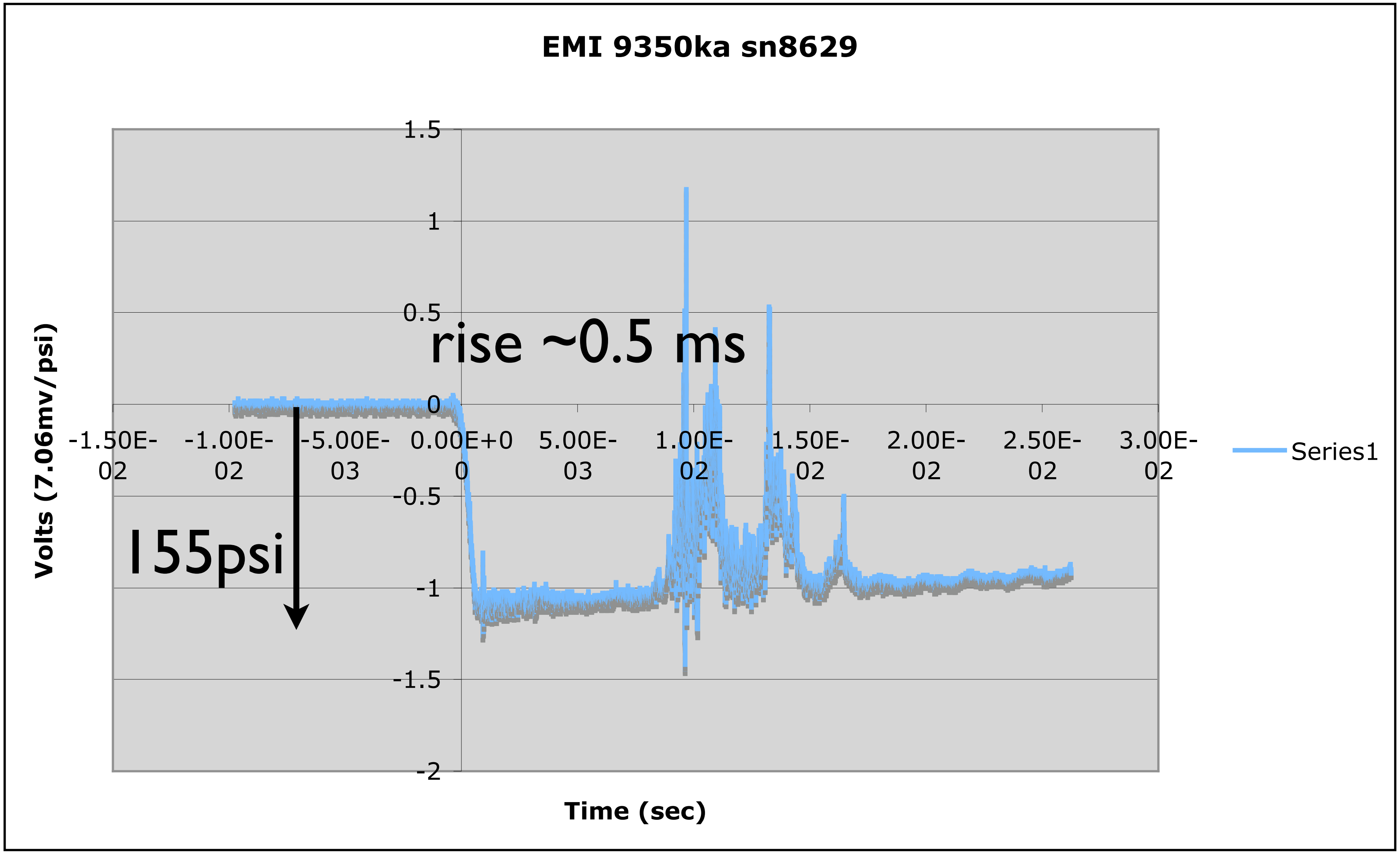
sensor at 40 inch

No shock wave because tank too small

ETL tube #2

broke at 104 psi   sn 8629   2 microsec/frame

Broke at 104 psi

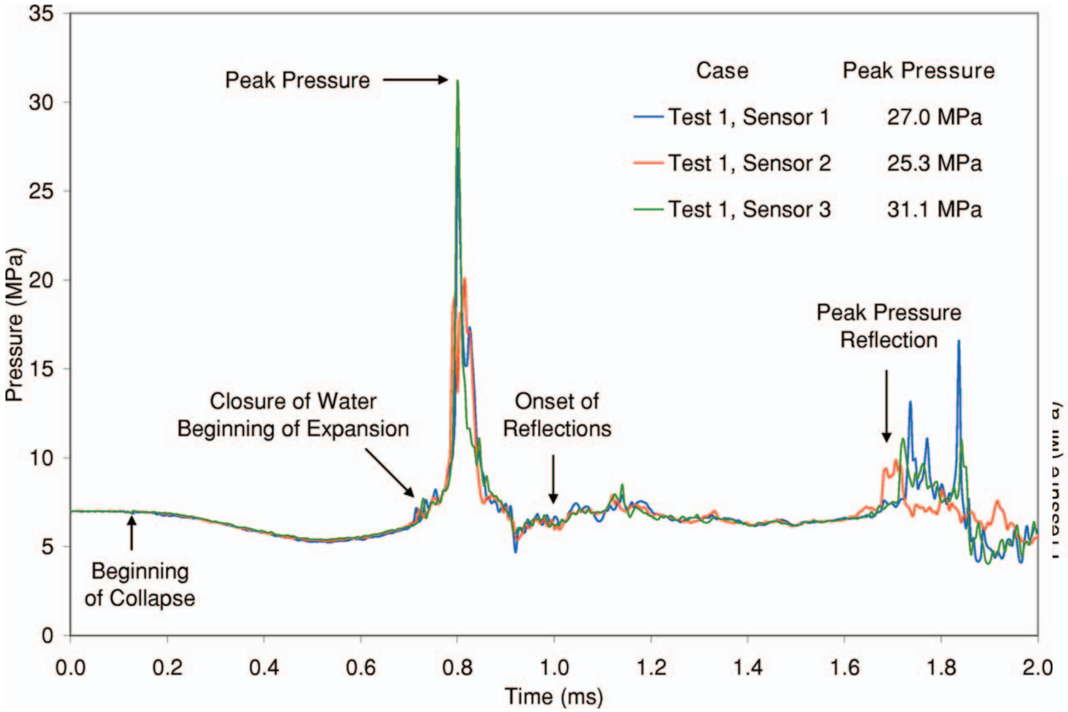


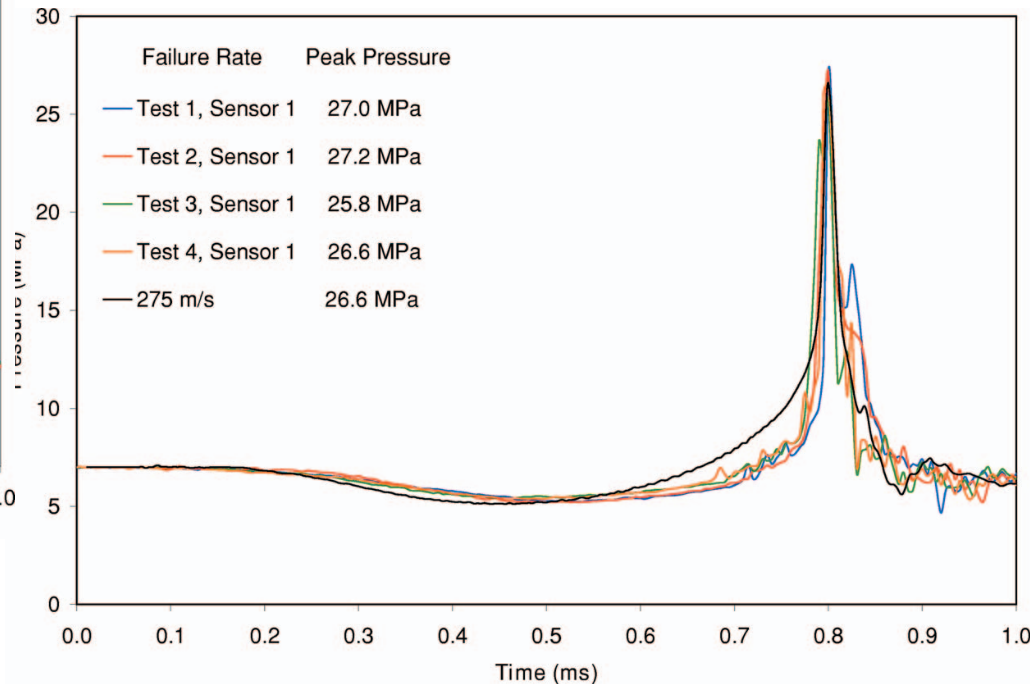
sensor at 40 inch

Materials

- http://nwg.phy.bnl.gov/~diwan/300kt/
- analysis example
  - J. Acoust. Soc. Am. 121 (2), Feb. 2007
  - Stephen E. Turner, Underwater implosion of glass spheres, Naval Undersea Warfare Center, Newport RI.

Simulation from paper





Possible Team for this work

- BNL: Milind Diwan, Ken Sexton (measurements)
- BNL: Nick Simos, Steve Bellavia (Computational Fluid Dynamics).
- NUWC (Navy Undersea Warfare Center): Stephen Turner, Joseph Ambrico (DYSMAS, measurement facilities)
- CAE associates.

Meetings

- Meeting was held with CAE associates to inform and get opinion on our work. 6/16/2009
- Second Meeting was held on 7/13/2009 (Monday) with NUWC and CAE.

General conclusions

- It may not be possible to model the initial pressure pulse within a factor of a few.
- Model will require benchmark tests.
- Model can be made to agree with tests by varying some parameters, but it is difficult to judge validity.
- An initial pressure pulse depends on materials. In particular, the pressure pulse depends on the speed with which the material is torn.
- Also depends on geometry of the nearby structures. i.e. water has to be available for inflow.

Continued

- An initial evaluation assuming instantaneous failure is underway, but will overestimate the pulse by at least a factor of 2 and as much as a factor of 10.
- It is likely that with the smaller volume of R7081, there is no shock wave or minimum mitigation is needed at 6-7 bar.
- Propagation of the shock wave can be done with same code.
- Evaluation of whether a tube breaks under a static plus a dynamic load is not possible without testing.

Capabilities

- NUWC can do the needed calculations.
- NUWC also has testin facilities.
- Testing with explosive charges is possible.
- a 10 ft diameter tank upto 100 bar exists in New Port RI.

FIG. 1. Test stand with test sample and instrumentation installed.

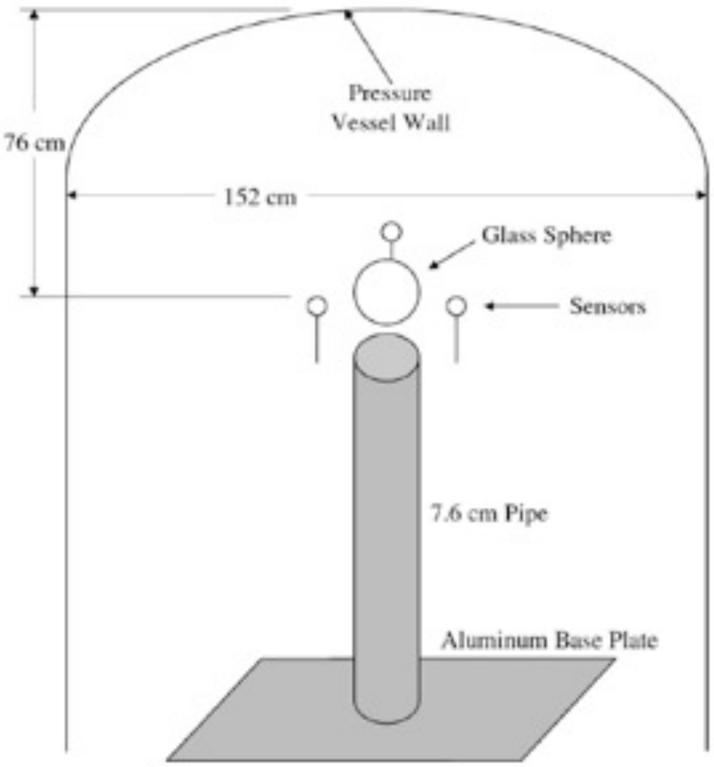


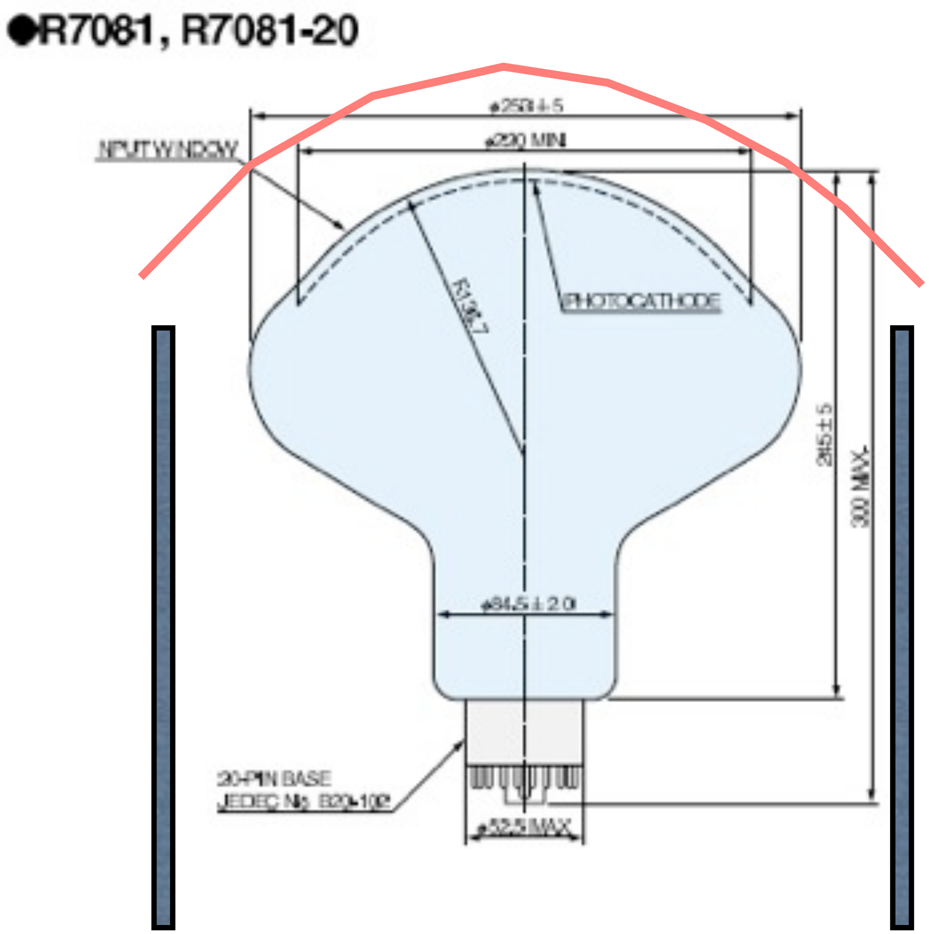
FIG. 2. Test stand schematic.

Plan for work

- Initial calculations from NUWC.
- Start work on water proof base design to evaluate what potting does to pressure performance. No data here. Might do 2 tests.
- Perform at least one test in the NUWC tank with their instrumentation.
- Initial evaluate of 3 choices for a baffle.
- CAE/BNL will evaluate effect of baffle on pressure pulse.
- Test at NUWC with explosive charges on several tubes.

Baffle choices

Cover if needed



Cylindrical baffle. Material: acrylic, polypropelene, fabric.

evaluate with and without cover.

Summary

- We have the intellectual and hardware resources for the pressure performance evaluation and design.
- Some issues regarding agreements with outside organizations
- There is not much engineering $ in S4 or DOE side of the budgets for this work because it got tossed back and forth. Might need to think about this.